R E P O R T R E S U M E S

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A PILOT STUDY IN ADVANCED INSTRUMENTATION FOR TECHNICAL INSTRUCTORS.

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A 2-WEEK SUMMER INSTITUTE TO PROVIDE INSERVICE TEACHERS WITH CURRENT INFORMATION ON THE PRACTICES AND CONCEPTS OF INDUSTRIAL INSTRUMENTATION WAS CONDUCTED AT RUTGERS UNIVERSITY. THE CURRICULUM WAS FOCUSED ON POST-HIGH SCHOOL, 2-YEAR INSTITUTIONAL NEEDS, WITH ADAPTATIONS DRAWN FOR THE HIGH SCHOOL LEVEL. A LEARNING EVALUATION OF PARTICIPATING TEACHER-STUDENTS WAS ACHIEVED BY USE OF DATA ON PERFORMANCE TEST SCORES, OBSERVATIONS, AND REACTIONS OF STUDENTS TO THE INSTITUTE. CONCLUSIONS BASED ON THESE DATA INDICATED THE NEED FOR AN INCREASE IN INSTRUMENTATION INSTRUCTION AND THE DIFFICULTIES IN ACQUIRING COMPETENT INSTRUCTORS. ONE OF THE SOLUTIONS TO THE NEED FOR INSTRUCTOR COMPETENCE APPEARED TO BE THE PROVISION OF FUNDAMENTAL INFORMATION AND LABORATORY EXPERIENCE TO INSTRUCTORS ALREADY KNOWLEDGEABLE IN SUCH FIELDS AS ELECTRONICS, HEATING, REFRIGERATION, AND AIR-CONDITIONING. IMPLICATIONS OF THE PROJECT SUGGESTED THAT SUCH INSTRUCTIONAL MATERIALS AS CURRICULUM GUIDES, COURSE OUTLINES, AND INFORMATION AND JOB SHEETS COULD BE DEVELOPED AS PART OF INSTITUTE EXPERIENCE. CONTINUANCE OF THE INSTITUTE DURING THE FOLLOWING SUMMER WAS RECOMMENDED. (WB)

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FINAL REPORT

"A Pilot Study in Advanced Instrumentation for Technical Instructors"

RUTGERS - THE STATE UNIVERSITY

NEW BRUNSWICK, NEW JERSEY

Initiated By

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August 31, 1965

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Mr. H. R. Karp	Mr. J. W. Murdock	Mr. D. S. Luppold
Mr. Robert Mayer	Mr. M. D. Weiss	Mr. G. M. Crabtree
		Mr. E. A. Weiss

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Mr. W. H. Furry
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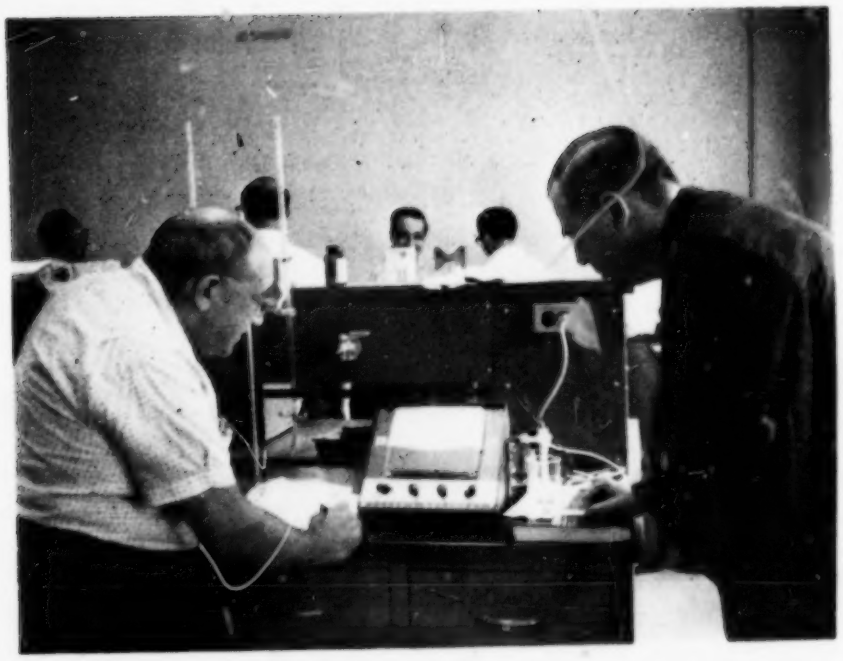
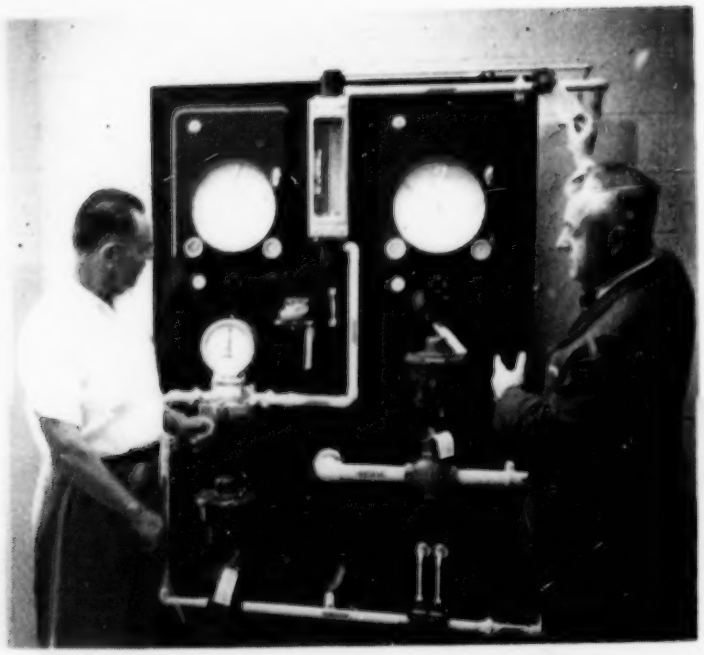
Moore Products Company
Mr. R. H. Owens
Leeds and Northrup Company
Mr. R. R. Hartman

The industrial firms that made possible the field study visitations:

Public Service Gas and Electric Company
Mr. Clyde Ruffle
Mr. W. W. Maull
RCA Laboratories
Dr. Jerome Kurshan
Mr. H. L. Cooke

THE CLASS IN INSTRUMENTATION





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SUMMARY

Today, the need exists for technicians educated in the field of instrumentation. This can only happen if adequate numbers of teachers exist who have been prepared to provide this instruction. The supply of such teachers is highly inadequate. Therefore, efforts to correct this situation are mandatory if the solution to the problem is to be achieved.

As a result, Rutgers - The State University sought and secured approval for a grant under Section 4(c) of the Vocational Education Act of 1963 to offer a summer Institute in Instrumentation for in-service teachers. This Institute provided current information together with laboratory applications to strengthen individuals who are presently teaching in this field, as well as to aid those desiring to enter the field, or who planned to incorporate some instrumentation into existing courses.

The emphasis of the Institute was on environmental and quantitative-qualitative types of instrumentation principles and practices, with instructional personnel secured from industrial users of instrumentation. Each instructor was highly proficient in his own speciality and had prepared appropriate materials for lecture-discussion sessions (three hours) and for the afternoon laboratory session (three hours).

Support learning activities included field study visitations and demonstrations — explanations by various manufacturers of instrumentation equipment.

Evaluation of students' learning experiences consisted of such activities as performance tests, written tests, discussion and observation of student activities.

Evaluation of the success of the Institute was based upon the reactions of the students as reflected in an opinionnaire, in letters, and in daily contact with the students in and out of class. Further evaluation was obtained from the reaction of the guest lecturers, consultants and laboratory instructional staff. The Institute was an excellent pilot study and a successful effort achieving to a very high degree the objective identified. Every student, in answer to the question on the opinionnaire, stated that the Institute was a success and that he would like to attend another Institute next year in instrumentation at Rutgers - The State University.

A desirable by-product of the Institute was the development of practical instructional materials by the participants. These included: curriculum guides, course outlines, information sheets, and job sheets.

It is recommended that another pilot study institute be held next summer for a three-week period, providing more laboratory time and introducing some instrumentation as related to electronics. Provision for stipends for students, in keeping with that provided by the National Science Foundation, is highly desirable. Relation of the Institute to curriculum development in the field of instrumentation is also recommended.

BACKGROUND

Today, technicians are an important part of the team effort of craftsmen, technicians, engineers and scientists in the expanding horizons of industry in the areas of technology and science. Instrumentation is an important part of the work of technicians.

Communication by Telstar, exploration of the ocean's depths, computerized power, oil, and gas industries, automated engine block manufacturing lines, and computerized telegraphy systems are but a few of the applications of industrial instrumentation. Without essential instrumentation, no innovation could have taken place in these fields.

The need for technicians is great. This is reflected in industry and reported in the current literature of both industry and education. The need for competent teachers of technicians is even greater.

How are educational institutions at the high school and post high school level going to secure qualified teachers in this rapidly growing and important technical field? How are the teachers presently employed going to gain the knowledge and skill needed to teach instrumentation effectively? If highly qualified teachers are not available, the students who later become technicians will be seriously handicapped. This restricts the total team effort of the technological team.

Therefore, recognizing this need, Rutgers - The State University in cooperation with the United States Office of Education under a grant made possible by the Vocational Education Act of 1963, Section 4 (c), sought a solution to the problem by providing a summer institute in instrumentation for teachers.

The introductory level institute on the principles and applications of industrial instrumentation, which was offered during the summer of 1964, provided some direction and reflected the need for greater "depth" in specific areas. As a result, the program of instruction for the pilot Institute of 1965 was planned to provide such "depth" in instrumentation for the participating teachers.

PURPOSE

The purpose of the pilot study - Recent Developments in Technical Education -- Instrumentation (Advanced I) - was to provide current information, coupled with applications, to upgrade in-service teachers in New Jersey and other states in the concepts of industrial instrumentation.

It was the goal of the Institute to contribute opportunities to develop understanding, knowledge and skill in the theory and applications of measurements in the field of industrial instrumentation. More specifically, the Institute, in a minimum period of time, provided opportunities for the students to:

a. Acquire knowledge of methods and instruments commonly used for measurement in industry.

b. Become familiar with the concepts of physically measured quantities and magnitudes.

c. Learn applications of instrumental methods to problems of industry.

d. Learn general and some special experimental techniques applicable to measurements.

OBJECTIVE

Specifically, the purpose was to provide current information, coupled with applications, to upgrade in-service teachers in the practices and concepts of industrial instrumentation.

CURRICULUM

Consultation with specialists in the field of industrial instrumentation and with other educators resulted in the development of the curriculum for the intensive two-week Institute. The curriculum was focused on the need of the post high school two-year institutions, with adaptations to the high school level.

COURSE OUTLINE

I. Introduction to instrumentation

II. Temperature-types of instrumentation
- A. Thermocouples
- B. Filled thermal systems
- C. Resistance types
- D. Readout devices

III. Instrumentation using the flow principle
- A. Orifice
- B. Venturi
- C. Pitot nozzle
- D. Readout devices

IV. Instrumentation for liquid analysis
- A. pH devices
- B. Electrolytic conductivity measurements
- C. Oxidation-reduction fundamentals
- D. Titrations
- E. Readout devices

V. Instrumentation for gas analysis
- A. Differential thermal types
- B. Magnetic applications
- C. Chromotography
- D. Density measurements
- E. Readout devices

VI. Pressure-types of instrumentation
- A. Manometers
- B. Deadweight testers
- C. Diaphragm
- D. Bellows
- E. Bourdon tube
- F. Readout devices

VII. Level-types of instrumentation
- A. Float
- B. Pressure
- C. Bubble
- D. Diaphragm
- E. Differential pressure
- F. Readout devices

VIII. Review, summary, and evaluation

COURSE ORGANIZATION

The course was organized with a three-hour period in the morning for lecture-discussion learning experiences. Presentations were made utilizing slides, charts, text and mimeograph materials, as well as chalkboard illustrations. Demonstrations and student participation experimentation, utilizing the principles previously discussed, were provided during the three-hour laboratory period.

Enrichment of the course was provided by two field study visitations. Selection of industrial plants was made to provide maximum opportunities to study a variety of actual instrumentation under actual industrial conditions. Instrumentation in a research and development organization was studied, plus the instrumentation used in an ultra-modern electric power plant.

Familiarity with common types of instrumentation was further provided by four displays of prominent manufacturers of instrumentation equipment.

FACULTY AND SUPPORT PERSONNEL

The Institute was a function of the Department of Vocational-Technical Education, Rutgers - The State University. The Institute was under the direction of Milton E. Larson, who is the Adviser in Technical Education and a full-time faculty member of the Graduate School of Education. He has a background of twenty-five years in technical education and industry, including such experiences as Director, Technical Education Center, Clearwater, Florida; member of the faculty, Applied Sciences Department, Flint Community College, Flint, Michigan; member of the faculty, Dunwoody Industrial Institute, Minneapolis, Minnesota.

Joseph E. Casey, Director of Educational Programs of the Leeds and Northrup Company, Philadelphia, Pennsylvania, served as co-ordinator and consultant for the Institute. Mr. Casey holds three degrees in engineering and business administration. He is a recognized authority in the field of instrumentation. He has served industry for many years as a consultant and industrial educator.

Nicholas F. Frigiola, Director of Technical Education of the State Department of Education of New Jersey, Trenton, and also member of the County College Advisory Committee, served as an adviser for the Institute. He has had a long career in education and industry. He is recognized for his technical knowledge and competence, as well as his leadership in the field of technical education.

The following individuals served as guest lecturers for one session each:

NAME	POSITION	EMPLOYER
H. R. Karp	Managing Editor "Control Engineering"	McGraw-Hill Co. New York City
Robert Mayer	Chief of Operation Physics Section	Research Center Sun Oil Co. Newtown Square, Pa.
J. W. Murdock	Head Applied Physics Division	Naval Boiler and Turbine Laboratory Philadelphia, Pa.
M. D. Weiss	Manager Analysis Instrumentation Group	U. S. Rubber Co. Naugatuck, Conn.
D. S. Luppold	Administrator of Technical Training	Leeds and Northrup Co. Philadelphia, Pa.
G. M. Crabtree	Lecturer	Technical Institute Division Temple University Philadelphia, Pa.
E. A. Weiss	Director of Corporate Planning	Sun Oil Company Philadelphia, Pa.

STUDENTS

The pilot Institute class was composed of 16 students. This was an ideal size for the laboratory activities. The residence of these students reflected a national and international point of view. Ten students were residents of New Jersey; two of New York; two of Vermont; one of Pennsylvania; and one of Canada. (See Appendix C for a complete list of participants.)

FACILITIES AND EQUIPMENT

Through the cooperation of Dean Easton, of the College of Engineering, Rutgers - The State University, the excellent facilities of the College of Engineering were used for the Institute. A laboratory in the Chemistry Division, under the

Chairmanship of Dr. Stett, was utilized for demonstrations and experimentation. Two rooms in the Mechanical Engineering Division, under Dr. Page, were utilized for classroom and display areas. The hydraulics laboratory in Ballantine Hall, under the direction of Dr. Granstrom, and Mr. Schwartz, was utilized effectively for one laboratory session.

In addition to equipment purchased, additional equipment was made available for laboratory activities by The Extension Division of Rutgers - The State University and by the Leeds and Northrup Company, Philadelphia, Pennsylvania.

Instrumentation equipment displays were provided by:

FIRM	ADDRESS
Foxboro Company	Foxboro, Massachusetts
Honeywell, Inc.	Philadelphia, Pennsylvania
Moore Products Company	Spring House, Pennsylvania
Leeds and Northrup Company	Philadelphia, Pennsylvania

FIELD STUDY VISITATIONS

Extremely educational field visitation experiences were provided as a coordinated learning activity through the cooperation of:

ORGANIZATION	VISIT TO
Public Service Gas and Electric Co. Clyde Ruffle, Director of Public Relations Newark, New Jersey	Hudson Generating Station W. W. Maull, Superintendent Jersey City, New Jersey
RCA Laboratories Jerome Kurshan, Manager, Research Services Laboratories Princeton, New Jersey	David Sarnoff Research Center H. L. Cooke, Manager Technical Relations Princeton, New Jersey

EVALUATION OF STUDENTS' LEARNING

Evaluation of students' learning was achieved by the use of performance tests, written tests and observation, coupled with the reaction of students to the Institute. All of these factors, plus the observations and comments of the personnel involved, indicate a very successful pilot Institute. (Evaluation instruments are given in Appendix B.)

EVALUATION OF SUCCESS OF INSTITUTE

To secure some measure of the effectiveness of the Institute, the reaction of the participants was determined by means of a student opinionnaire. Since all students were mature individuals, interested in utilizing instrumentation knowledge directly or indirectly in their teaching activities, this is a significant measure of the success of the Institute. The questions and responses follow:

SUMMARY OF STUDENT OPINIONNAIRE

1. Are you interested in attending another Instrumentation Institute at Rutgers - The State University next year, if one is offered?
   Yes - 100 per cent response of students

2. If you were to attend such an Institute next year, would you prefer a 1, 2, or 3 week Institute?
   The majority indicated a preference for a 3 week Institute; 2 week period was a second choice.

3. What month of the year is most desirable for an Institute?
   70 per cent favored July.

4. If you know of other people from your school who might be interested, write the number that you think might participate from your school.
   Total number of people suggested is 49.

5. Do you favor a full-day Institute?
   Approximately 60 per cent favored a full-day Institute.

6. Do you favor a laboratory period?
   Approximately 80 per cent desired a laboratory period.

7. Do you favor Field Study visitations?
   This was favored by all of the students.

8. Do you think this Institute was a success?
   The response of the participants was unanimously of the opinion that the Institute was a success.

9. Will you teach a course in Instrumentation next year?
   Approximately 40 per cent said, "yes".

10. Will you introduce some Instrumentation materials into your present courses next year?

    100 per cent indicated that they would introduce some Instrumentation into their present courses.

11. What type of written Term Project would be most helpful to you if you were to take a Summer Instrumentation Institute next summer?

    Most frequently mentioned were the development of course materials: course outlines, information sheets, job sheets, etc.

12. What was the most helpful part of this Institute?

    Approximately 70 per cent indicated that the lecture-discussion sessions of the guest instructors were the most helpful. Others suggested the laboratory sessions and the Field Study visitations as the most helpful experiences of the Institute.

NOTE: The above opinionnaire was given to the students of the class on Tuesday, July 20, 1965.

While it reflects some of the reactions of the students, as one student indicated, it is impossible to measure the benefits that we and our students will derive from this Institute. I know it helped me a great deal !

CONCLUSIONS

Based upon the information gained during and after the completion of the pilot study - Instrumentation Institute - the following conclusions seem justified:

1. Instrumentation is becoming more important in industry and is vital to automation, semi-automation, and many production and service activities.
2. Increased numbers of technicians are desired in the field of instrumentation.
3. More and more high school and post high school vocational-technical institutions are becoming aware of the need for instrumentation instruction.
4. As high school and post high school institutions recognize the need for instrumentation instruction, they also experience the difficulty of securing instructors competent in this field.
5. One of the solutions to the need for instructors' competence in the field of instrumentation seems to be to provide fundamental information and basic laboratory experience to instructors already knowledgeable in such fields as electronics, and heating, refrigeration, and air-conditioning.
6. An intensive summer Institute in Instrumentation can provide much desired information and laboratory experiences to aid new instructors entering upon the responsibilities of teaching instrumentation.

7. Basic fundamentals of physics and chemistry need to be integrated into the instruction in the principles and practices of instrumentation.

8. Fundamentals of instrumentation must be related to actual experiences and to basic laboratory experimentations and demonstrations.

9. Field study visitations are essential to strengthen a knowledge of applications in industry.

10. Provision for the development of practical instructional materials, such as curriculum guides, course outlines, information sheets and job sheets, are highly desirable activities that can be developed as part of an institute experience.

RECOMMENDATIONS

As a result of the experience of this pilot Institute, the following recommendations are made:

1. Continue for further refinement and teacher up-dating the institute in instrumentation during the summer of 1966.

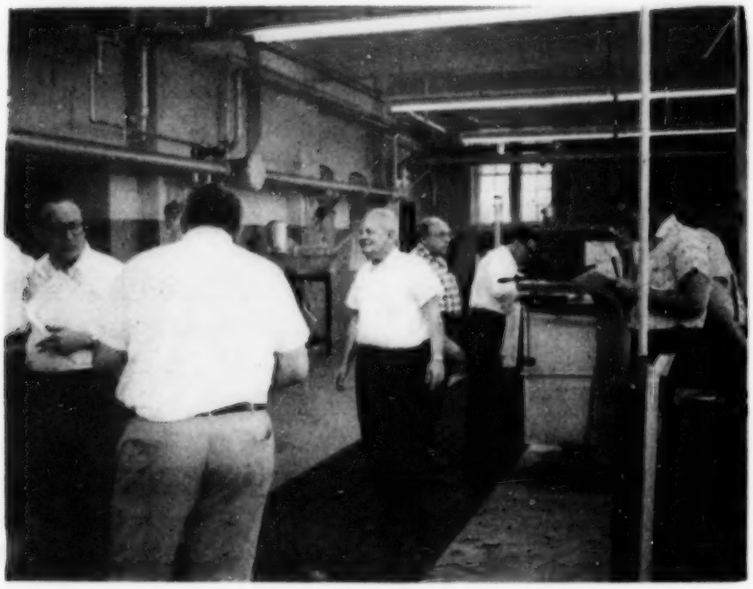
2. Lengthen the time of the Institute to three weeks, providing additional time for expanded laboratory activities and additional emphasis on instrumentation as related to electronics.

3. Continue utilizing the services of outstanding guest lecturers and expanding the emphasis on laboratory activities.

4. Provide stipends in keeping with those of the National Science Foundations. This is essential for instructors, to free them of the financial problems, and to permit others to come who otherwise could not.

5. Preparation of a laboratory manual has been considered. This manual would supplement Technical Education Program Series No. 6, Instrumentation Technology, OE-80033. Such a manual would fill a vital need. This would need to be a separate contract under an appropriate act for funding.

PHOTOGRAPHS TAKEN DURING THE INSTRUMENTATION INSTITUTE



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Appendix A

Instructional Materials

INSTRUMENTATION -- INFORMATION SHEET

DIRECTIONS: Prepare information sheets on the subjects identified. Plan these for students in two-year post high school technical classes, unless otherwise specified. Develop these for actual class use. Even though information sheets vary considerably as to content and style, consider the following as guides in the development of these instructional aids.

EXPLANATION

1. Clear
2. Concise
3. Brief
4. Define new words or unusual meanings
5. Illustrate - sketches, charts, etc.
6. "Gear" to needs and background of students
7. Complete and logical
8. English correctly used

APPLICATIONS

1. Think in terms of applications meaningful to student and essential to course
2. Relate to a few varied industrial situations

QUESTIONS AND SUMMARY

1. Develop a few good questions to aid students in determining whether or not understanding has been achieved.
2. A brief summary statement may be helpful to unite the concepts in the minds of the students.

SUGGESTED SUBJECTS FOR INFORMATION SHEETS

A. INTRODUCTION TO INSTRUMENTATION
1. The function and importance of instrumentation
2. Basic principles of physics related to instrumentation
3. Relation of instrumentation to modern industry
4. Other: _____

B. TEMPERATURE
1. Temperature scales
2. Kinds of thermometers and their applications
3. Kinds of thermocouples and their applications
4. Filled thermal systems
5. Resistance thermometers
6. General temperature measuring practices
7. Other: _____

C. FLOW
1. Principles of flow measurement
2. Direct flow measurements -- positive displacement
3. Inferential flow measurements -- venturi, orifice, etc.
4. Flow calculations
5. Other: _____

D. LIQUID ANALYSIS
1. Principles and uses of liquid analysis
2. pH measurements
3. Electrolytic conductivity
4. Oxidation/reduction - Titration
5. Other: _____

E. GAS ANALYSIS
1. Thermal-conductivity analyzers
2. Magnetic gas analyzers
3. Chromotography
4. Density and Specific gravity
5. Other: _____

F. PRESSURE
1. Pressure measuring instruments
2. Manometers
3. Elastic deformation elements
4. Dead-weight testers
5. Other: _____

G. LEVEL
1. Direct measurement -- float and similar types
2. Inferential level types
3. Other: _____

INSTRUMENTATION -- EXPERIMENTATION-DEMONSTRATION LABORATORY INSTRUCTION SHEET

DIRECTIONS: Prepare the EXPERIMENTATION-DEMONSTRATION LABORATORY INSTRUCTION SHEET as a teaching aid for the Laboratory Session.

TITLE: _____
(Of Laboratory experiment or demonstration)

OBJECTIVES:
1.
2. (etc.)

GENERAL INSTRUCTIONS:
1.
2. (etc.)

EQUIPMENT, TOOLS AND MATERIALS:
1.
2. (etc.)

PRECAUTIONS:
1.
2. (etc.)

PROCEDURAL STEPS:
1.
2. (etc.)

SKETCHES:
(If needed)

REFERENCES:
1.
2. (etc.)

(NOTE: Expand this suggested format by adding pages as needed)

SUGGESTED LABORATORY PROJECTS

PRESSURE GAUGES

1. Compare and calibrate the following pressure gauges against known standards, then make a series of pressure measurements:
   (a) Manometer
   (b) Bellows
   (c) Bell gauge
   (d) Bourdon tube
2. Choose a gauge capable of making a differential pressure measurement. Determine its range of measurement and maximum safe input pressure.
3. Choose two gauges of the force-balance principle, and make a series of pressure readings.
4. Install a pneumatic pressure transmitter in a pneumatic circuit, and make a series of relative readings of input and output transmitter pressures. Prepare a table of input vs. output pressure readings for comparison

*(Pages 17-18)

LIQUID AND GAS-FLOW MEASUREMENTS

1. Using positive displacement meters, after suitable calibration, as the standard reference, determine the pressure differentials and the flow rates for the following:
   (a) Venturi meters
   (b) Orifice plate meters
   (c) Variable area meters
   (d) Weirs
2. From the data obtained, determine the coefficients for the various combinations tested and the value of the Reynolds number for each test.

*(Page 18)

LIQUID LEVEL MEASUREMENTS

1. Using the diaphragm box, plot pressure as a function of the depth of the box. Repeat the experiment, using different liquids if available.
2. In a tank with controlled depth, use a purge or bubbler system to measure liquid depth. Plot pressure vs. depth for liquids of different specific gravities. Consider any problems encountered in this determination.
3. Plot pressure vs. height of liquid for a series of liquids of different specific gravities. Determine feasibility of ascertaining depth (or height) of liquid in this manner.

4. Using available force-balance pressure devices, compare their performance with the diaphragm box, purge or bubbler system.
5. Evaluate all devices in terms of their accuracy and ease of use.

*(Page 18)

TEMPERATURE MEASUREMENTS

1. Using gas-filled and liquid-filled thermometers, measure the temperature of different fluids at various temperatures. Determine the relative accuracy of measurement for each type of thermometer time-constants.
2. By varying the temperature of the fluid(s), determine the thermometer time-constants.
3. Determine the factors affecting the time-constants of the thermometers.
4. Vary the locations of a thermometer in a fluid, then:
   (a) Agitate the fluid.
   (b) Still the fluid.
   (c) Vary the location of the thermometer in the liquid.
   (d) Add a protective well around the thermometer.
   Compare responses.

*(Page 19)

SPECIFIC GRAVITY MEASUREMENTS

1. Measure the specific gravities of several fluids by using pneumatic specific gravity bubbler systems. Devise a scale of specific gravities based on pressure.
2. Compare the specific gravities of several fluids when using different scales. Determine a correlation factor (or factors) which permit conversion from one scale to the other.
3. Design a pneumatic or hydraulic transmitter, the output of which will be proportional to the specific gravity.

*(Page 19)

NOTE: The above projects are listed in:
Instrumentation Technology - A Suggested 2-Year Post High School Curriculum (OE-80033), Washington: U. S. Department of Health, Education, and Welfare, Office of Education, 1964.

*Pages as indicated in the above reference.

Appendix B

Instruments for Students' Evaluation

INSTRUMENTATION -- EXPERIMENTATION-DEMONSTRATION LABORATORY INSTRUCTION SHEET

TITLE: MEASUREMENT OF TEMPERATURE USING RESISTANCE THERMOMETERS

OBJECTIVES:

1. Determine speed of response of bare element and in well

GENERAL INSTRUCTIONS:

1. Measure time to 63% of total change in resistance when R/T is shifted from one bath to the other.

EQUIPMENT, TOOLS AND MATERIALS:

1. Resistance thermometer
2. Wheatstone bridge
3. Resistance thermometer well
4. Hot water bath
5. Ice bath

PRECAUTIONS:

PROCEDURAL STEPS:

SKETCHES:

REFERENCES:

INSTRUMENTATION -- EXPERIMENTATION-DEMONSTRATION LABORATORY
INSTRUCTION SHEET

TITLE: OPERATION OF SELF-BALANCING POTENTIOMETER

OBJECTIVES:

1. Determine how the self-balancing potentiometer operates

GENERAL INSTRUCTIONS:

1. Observe operation of potentiometer as input is varied

EQUIPMENT, TOOLS AND MATERIALS:

1. Self-balancing potentiometer
2. Millivolt source

PRECAUTIONS:

PROCEDURAL STEPS:

SKETCHES:

REFERENCES:

INSTRUMENTATION -- EXPERIMENTATION-DEMONSTRATION LABORATORY
INSTRUCTION SHEET

TITLE: MEASUREMENT OF TEMPERATURE USING THERMOCOUPLES - A

OBJECTIVES:

1. Determine speed of response of base element, in ceramic well and in metal well.

GENERAL INSTRUCTIONS:

1. Measure time to 63% of total change in temperature as the T/C and wells are shifted between furnace and ambient.

EQUIPMENT, TOOLS AND MATERIALS:

1. Thermocouple (small wire)
2. Self-balancing potentiometer
3. Thermocouple well (ceramic)
4. Thermocouple (metal)
5. Furnace

PRECAUTIONS:

PROCEDURAL STEPS:

SKETCHES:

REFERENCES:

INSTRUMENTATION -- EXPERIMENTATION-DEMONSTRATION LABORATORY
INSTRUCTION SHEET

TITLE: MEASUREMENT OF TEMPERATURE USING THERMOCOUPLES - B

OBJECTIVES:

1. Determine speed of response of large and small wire bare element.

GENERAL INSTRUCTIONS:

1. Measure time to 63% of total change in EMF as each size wire T/C is shifted between baths.

EQUIPMENT, TOOLS AND MATERIALS:

1. Thermocouple (large wire)
2. Thermocouple (small wire)
3. Millivolt meter
4. Hot water bath
5. Cold water bath

PRECAUTIONS:

PROCEDURAL STEPS:

SKETCHES:

REFERENCES:

FINAL EXAMINATION

15:288:463 RECENT DEVELOPMENTS IN TECHNICAL EDUCATION -- INSTRUMENTATION

****WRITE ANSWERS ON THE ANSWER SHEET - NOT ON THE QUESTION SHEET****

Part I - Multiple Choice

Directions: Each of the questions or incomplete statements given below is followed by several possible answers. Choose the part that BEST answers the questions or completes the statement. Circle the identifying letter ONLY of the correct answer on the Answer Sheet opposite the corresponding number. Be sure to use corresponding numbers -- Part I on Answer Sheet must be used for Part I on the Question Sheet.

1. Which of the following resistance thermometers is useful over the greatest range? (a) copper (b) nickel (c) platinum.

2. In choosing a thermocouple for use in measuring a rapidly changing temperature, which of the following factors is most important? (a) linear output (b) resistance to corrosion (c) repeatability (d) size of wire.

3. Resistance thermometers must be constructed to have a strain-free winding and then annealed to achieve maximum (a) sensitivity (b) linearity (c) reproducibility (d) readability.

4. The following is a semi-conductor type temperature transducer when the negative temperature coefficient of resistance is negative. (a) resistance thermometer (b) thermocouple (c) thermistor (d) mercury thermometer.

5. A filled system containing the following material is non-linear. (a) mercury (b) nitrogen (c) xylene (d) butane.

6. The most accurate primary element from the standpoint of predicting flow without calibration is the (a) Venturi tube (b) flow nozzle (c) concentric orifice (d) pitot tube.

7. When a flow meter is calibrated, the coefficient of discharge is best analyzed by plotting it as some function of (a) head (b) Reynold's Number (c) Froude's Number (d) flow rate.

8. The chief disadvantage of the classic Venturi tube for process control applications is its (a) low accuracy (b) high differential (c) long length.

9. Calibration of a flow meter will improve its (a) tolerance (b) accuracy (c) precision (d) repeatability.

10. The largest industrial user of the concentric square-edged orifice is (a) natural gas (b) water works (c) central stations (d) process industry.

11. If you were to select the best method to measure the concentration of acetaldehyde in alcohol, you would select (a) potentiometric (b) amperometric (c) conductimetric (d) titrimetric method.

12. If the standard potential of hydrogen/zinc is -0.76 volts, and that of hydrogen/copper is 0.34 volts, the standard potential of zinc/copper would be (a) -1.10 volts (b) -0.42 volts (c) +1.10 volts (d) +0.42 volts.

13. The oxygen analyzer contains an electrolyte solution in a polyethylene membrane. Two platinum electrodes in the solution are held at the oxygen half-wave potential. The current flow that is measured is proportional to oxygen concentration. The electrochemical method used here is (a) potentiometric (b) amperometric (c) polarographic (d) conductimetric.

14. In the reaction $Fe^{++} + Ce^{++++} = Fe^{+++} + Ce^{+++}$ the Fe, Ce are being respectively (a) oxidized, oxidized (b) oxidized, reduced (c) reduced, oxidized (d) reduced, reduced.

15. The most useful process instrument for measuring hydrogen ion concentrations in aqueous solutions utilizes the following measuring electrode (a) metal/metal ion (b) gas/gaseous ion (c) membrane (d) metal in soluble salt.

16. A gas thermometer is calibrated for the interval of 300 to 1000°F. The span is (a) 1300°F (b) 1000°F (c) 700°F (d) 650°F.

17. A pressure gauge on a tank reads 30 psig. The absolute pressure in the tank is (a) 15.3 psia (b) 44.7 psia (c) 59.9 psia (d) 76 psia.

18. A 3 to 15 psig signal is applied to a receiving gauge. When the gauge reads 70% the applied signal is (a) 11.4 psig (b) 8.4 psig (c) 10.5 psig (d) 18 psig.

19. The point of minimum pressure in an orifice plate installation occurs slightly downstream from the plate and it is called (a) vena contracta (b) beta point (c) reference point (d) pitot point.

20. What is the downward force on the stem of a pneumatic control valve when a 15 psi control signal is applied to the diaphragm? The diaphragm has an area of 30 sq. in. (a) 450 lb. (b) 2 lb. (c) 45 lb. (d) 1972 lb.

21. The defining parameters for pressure are (a) force and distance (b) force and area (c) weight and area (d) weight and height.

22. A well type manometer has a scale length which measures in inches and tenths. The linear distance between inch divisions is (a) exactly one inch (b) greater than one inch (c) less than one inch (d) 25.4 millimeters.

23. Bellows pressure elements are ordinarily used to measure (a) high vacuum (b) absolute pressure (c) gauge pressures less than 100 psi (d) atmospheric pressure.

24. Differential pressure measurement is commonly used to infer (a) flow rate (b) gauge pressure (c) barometric pressure (d) density of mercury.

25. A vacuum gauge whose calibration is determined by gas laws and dimension only is the (a) Pirani gauge (b) thermionic vacuum gauge (c) thermocouple gauge (d) McLeod gauge.

26. Absolute pressure is equal to the gauge pressure (a) less atmospheric pressure (b) at sea level (c) plus atmospheric pressure (d) times the density of mercury.

Part II - True and False

Directions: If the statement is True, circle the T on the Answer Sheet; but if it is False, circle the letter F. Start with number 51 of Part II on the Answer Sheet. Use numbers on the Answer Sheet corresponding to the number of the items on the Test Questions.

51. A two-lead resistance thermometer is independent of lead length.

52. All devices commonly using the change in resistance as a measure of a change in temperature increase, increase in resistance as the temperature increases.

53. Inhomogenous wires are satisfactory as thermocouples.

54. Liquid filled systems can be used with capillary tubing of less than 100 feet without effecting accuracy.

55. Filled systems may be used over a wider range of temperatures than thermocouples.

56. A section of straight pipe could be used as a primary element of a differential flow meter.

57. Flow measurement using the primary element discussed in this course is very highly standardized compared with temperature measurement.

58. Upstream piping configurations can cause large errors in flow measurement, but these can be compensated for by using a more accurate transducer for differential measurement.

59. A sharp-edged concentric orifice can be used to meter flow in either direction.

60. The reverse-type pitot tube produces a larger differential for the same flow conditions than does the elementary type.

61. The conductimetric titration curve of a weak acid with a weak base has a very sharp end-point.

62. The conductance of solutions was studied by Arrhenius to explain his theory of electrolytic dissociation.

63. Electrochemical analysis is possible in all fluid mixtures whether liquids, gases, slurries or emulsions.

64. In order to measure the potential of an electrode exactly, a small current flow is needed.

65. In oxidation-reduction, the loss of electrons takes place at the anode and the gain of electrons takes place at the cathode.

66. The measurement of pH is always incorrect because any cell used for the measurement inevitably involves a liquid junction potential of more or less uncertain magnitude.

67. An 0-15 psi recording pressure gauge could be conveniently calibrated using a 30 inch mercury column as a standard.

68. The density of mercury is approximately three times the density of water.

69. The differential pressure across an orifice is directly proportioned to the flow rate through the orifice.

70. Atmospheric pressure is constant and standardized at 14. 73 psia.

71. Vacuum is a pressure below the prevailing atmospheric pressure.

72. Bourdon spring gauges ordinarily indicate or record "gauge pressure".

73. A chromel-alumel thermocouple is better than an iron-constantan when used in a reducing atmosphere.

74. A self-balancing thermocouple readout uses a positive temperature coefficient resistor to compensate for cold junction changes.

Part III-A - Matching

Directions: Write on the Answer Sheet of Part III, after the corresponding number, the letter of the item in Column II that best matches the phrase in Column I. Use the items in Column II only once.

Column I	Column II
101. Light refraction changes of liquids	a. Oxygen analyzer
102. Varying abilities of gases to transfer and absorb heat from resistance filaments	b. Gas chromotograph
103. Elution time of vapors differs in absorbing mediums	c. Refractometer
104. Radiation waves (2-15 microns) are absorbed in differing patterns for different liquids and gases	d. Thermal conductivity meter
105. A magnetic gas cools a resistor	e. Non-dispersive infrared analyzers

Part III-B - Short Answer

Directions: Write the answer to each question in one, two, or a few words, as indicated. Be sure the answer is written on lines corresponding to the number or numbers assigned to each question.

106.
107. What are the two basic principles of operation of filled systems?

108.
109. Name four physical phenomena used in temperature measurement.
110.
111.

112. A _____ is used to measure temperatures when they are too high to be measured with a mercury thermometer.

113.
114. List the 2 factors which will affect measurements taken with a pH meter.

115. Three unknown liquids give the following pH readings: liquid A, pH 7; liquid B, pH 13; liquid C, pH 3. Which of these liquids would neutralize a strong acid?

116. The simplest electrical temperature-sensitive device is the _____.

117. The most common type of bridge used with resistance thermometers is called the _____ bridge.

Part IV - Essay-Type Questions

Directions: Write the answers to each of the questions below on the Answer Sheet (reverse side) after the proper number. Be brief, direct, and to the point. Use the space as provided.

126. Explain why the square-edged orifice has the lowest numerical discharge coefficient of all the primary elements discussed in this course.

127. What is the one difficulty that distinguishes pH measurements with the glass electrode from all other electrochemical measurements?

128. Define pH.

129. What are the characteristics of pressure instruments of interest to the user?

130. What is the primary difference in the way that the pitot tube senses flow compared with the other primary elements discussed?

131. Under what conditions can electrochemical measurements be made using solvents other than water?

132. Give a brief discussion of the gas chromotography principle.

133. What is the function of the filter cell in infrared measurements?

Appendix C

List of Student Participants

PARTICIPANTS

July 7 - 20, 1965

NAME	TEMPORARY ADDRESS	PERMANENT ADDRESS	TEACHING ASSIGNMENT
Anthony, Gregory		24 W. Third St. Bayonne, N. J.	Electronics
Cherry, Norman J.	Livingston Hall	1780 Willis Ave. Merrick, N. Y.	Instrumentation
Cherry, Herbert	Clothier Hall	6532 N. 16th St. Philadelphia, Pa.	Electrical Shop
Condon, Joseph	Room 213 Brunswick Inn	Box 714, Labrador City Nfld., Canada	Iron Ore Co. of Canada
Emanuel, Alfred		25 Stockton Rd. Kendall Park, N. J.	Electronics Lab
Faris, Kamil J.		20 Garbarino Ave. Wanaque, N. J.	Refrigeration and Air Conditioning
Heidal, William J.		Crestview Apts. Rt. 9, Parlin, N. J.	E. R. Squibb & Sons
Jansen, George		11 Marchmont Lane Willingsboro, N. J.	Electronics-Instrumentation
Kirk, Edwin		18 Laurel St. Hawthorne, N. J.	Mathematics & Science
Prensky, Sol D.		208 Beverly Rd. Brooklyn, N. Y.	Instrumentation & Electronics
Schumacher, Frank G.		7 Pleasant Plains Rd. Franklin Park, N. J.	Instrumentation
Sicard, Charles H.	537 Livingston Hall	RFD #2 Randolph, Vt.	Chrm., Inst. Tech. Program
Trask, Irwin	537 Livingston Hall	RFD #2 Randolph, Vt.	Director, Mech. Technology
Vander-Roll, Leonard		870 Colonial Rd. Franklin Lakes, N.J.	Electricity
Williamson, Samuel D.		323 Franklin Blvd. Somerset, N. J.	Mathematics & Science
Wynn, Harry		72 Dover St. Newark, N. J.	Heating & Refrigeration

Appendix D

Illustrations of Letters Received From Participants

July 22, 1965

Dr. Milton E. Larson
Department of Vocational-
Technical Education
10 Seminary Place
New Brunswick, New Jersey

Dear Sir:

In reference to course No. 288:463 - "Recent Developments in Technical Education" - I would like the opportunity of informing you of the benefits which I have obtained.

I think that the Instructors were well chosen and very capable in the explanation and presentation of their subjects. Their Laboratory experiments were well chosen in reference to further explanation of their lectures as well as a practical suggestion for the class to take back to their respective schools to be used as part of the individual student's laboratory expe..ments.

The Field Trips, too, were beneficial. The trip to the Power Station was very good, in that it gave the members of the class an opportunity to see these instruments in actual use. (Controlling and recording.)

The trip to the laboratory at R.C.A. was excellent in that it showed us the needs of industry, both present and future, and also gave some idea of the knowledge our students will need to know when they graduate, and are looking for a spot in these industries.

I feel that the extra time spent this year in the laboratory was a worth while portion of the course; however, I feel that it could be expanded to cover the subject more deeply to help those related to but not definitely in the field understand it better.

If this course is presented again next year, I would like very much to be invited to join it, as I feel that I personally have obtained many ideas for future use in my classroom lectures and experiments.

Yours truly,

Frank G. Schumacher
7 Pleasant Plains Road
Franklin Park, New Jersey

72 Dover Street
Newark, New Jersey
July 18, 1965

Dr. Milton E. Larson
Graduate School of Education
10 Seminary Place
New Brunswick, New Jersey

Dear Sir:

This course has presented a definite picture of the recent developments in instrumentations. This course is a must for those in the vocational field because of the importance of automation and technical knowledge in our present society. The teacher must be aware of these trends and impart his knowledge to his students.

I feel that this course provides the teacher with the necessary background for aiding his students. The course gives a sampling of many industrial advances and in many cases delves deeply into these "innovations".

I particularl, enjoyed the casual atmosphere and pleasant surroundings which aided learning and really fostered my interest in the course. I feel that the course was well-planned because in the course of ten days we covered a quantity of pertinent material.

I feel that a pre-requisite course would enhance this present course. The initial course would possibly consist of an introduction to instrumentation and some of the philosophy behind it.

The laboratories provided the first-hand experience of seeing theory in practice. These experiences made the course very interesting to me and much more meaningful than straight theory.

In summary, I enjoyed this course and feel that it has given me a new and deeper understanding of instrumentation.

Sincerely,

Harry L. Wynn
Instructor - Essex County
Vocational and Technical
High School

25 Stockton Road
Kendall Park, New Jersey
July 19, 1965

Dr. Milton E. Larson
Graduate School of Education
10 Seminary Place
New Brunswick, New Jersey

Dear Dr. Larson:

It has been a pleasure to participate in the current Instrumentation Institute. The sessions have been most stimulating and the guest lecturers were well chosen.

The laboratory experiments served to back up the theory with practical usage and provided a needed "feel" for the various instruments. In addition we were able to see for ourselves some of the advantages and limitations of certain measuring devices and techniques. The commercial exhibits gave us a chance to see and compare units of comparable size and price to perform a desired function. The exhibitors, especially Leeds and Northrup, provided excellent supplementary literature. Last, but not least, we were able to exchange ideas and compare notes with others from both New Jersey and other areas.

I hope to be invited to attend any future Institutes of this nature.

Respectfully yours,

Alfred Emanuel

6532 N. 16th Street
Philadelphia, Pennsylvania
July 23, 1965

Dr. Milton E. Larson
Adviser, Technical Education
Rutgers University
New Brunswick, New Jersey

Dear Dr. Larson:

I want to thank you very much for the opportunity given to me to attend the Instrumentation Institute. The lectures and the laboratory experiences were of excellent quality, and it was a pleasure to listen and work under the guidance of such excellent teachers.

I am sure that the rest of the class appreciate the amount of work that you and the staff did in order to organize such a program of high level and quality.

I would appreciate it very much if you would place my name on your mailing list so I can be notified of your next summer session.

Please extend my regards to all your staff.

Have an enjoyable vacation and rest.

Sincerely yours,

Herbert Cherry

VERMONT TECHNICAL COLLEGE
RANDOLPH CENTER, VERMONT 05061
AREA CODE 802 728-3391

22 July 1965

Dr. Milton E. Larson
Department of Vocational-
Technical Education
Graduate School of Education
Rutgers - The State University
New Brunswick, New Jersey 08903

Dear Sir:

The instrumentation course which I just completed, gave me considerable insight into the problems of instrumentation, and also some vital information for the new course in instrumentation which we are starting at V. T. C. this September.

The lecturers from industry were well qualified to provide us information in the area of instrumentation and the assistance in the labs was excellent.

The two field trips were good examples of the application of instrumentation and the one to David Sarnoff Labs gave me many ideas as to what the future problems of industry could be.

I enjoyed the course very much and would return if another such course were offered.

Sincerely yours,

Irwin A. Trask

Proff. Irwin A. Trask
Department Head
Mech. Technology

Appendix E

Illustrations of Curricular Materials Developed by Student Participants

LABORATORY EXPERIMENT SHEET

TITLE: Manometer Calibration

OBJECTIVES:

1. To compare manometer readings against a standard.
2. To make a series of measurements using manometers.

GENERAL INSTRUCTIONS:

1. Hook up manometers to a variable air regulator and observe height of columns.

EQUIPMENT:

1. 0 - 36" water manometer
2. 0 - 20" mercury manometer
3. 0 - 5 psi variable air regulator
4. Manometer conversion table
5. Tubing and wrenches

PRECAUTIONS:

1. Handle manometers with care.
2. Do not exceed range of manometers.
3. Do not allow mercury to come into contact with any breaks in the skin.

PROCEDURE:

1. Check manometer scales for zero reading.
2. Connect manometers in parallel with regulator. (See Fig. 1)
3. Apply air pressure in steps equal to 5" of water.
4. Record manometer readings for each step up to 35" of water.
5. Plot readings and compare to conversion table.

REFERENCES:

1. Eckman, Donald P., Industrial Instrumentation John Wiley & Sons, New York, 1950, Chapter 8
2. ISA - RP2.1 Recommended Practice - Manometer Tables Instrument Society of America, Pittsburgh, 1959
3. ISA - RP11.1 Recommended Practice - Mercury Handling Instrument Society of America, Pittsburgh, 1959

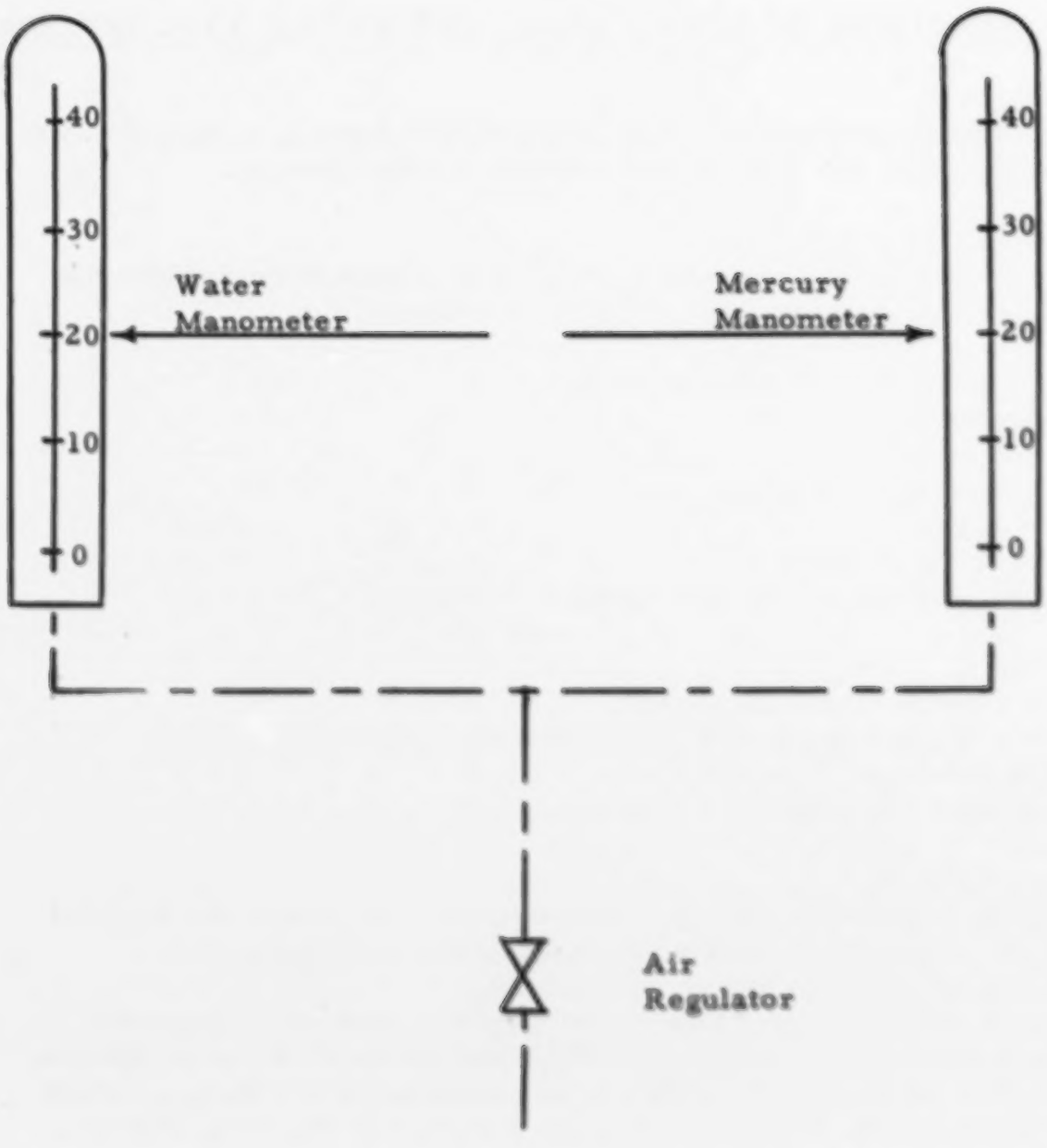
40
30
20
10
0
Water
Manometer
Mercury
Manometer
40
30
20
10
0
Air
Regulator

Figure 1

INSTRUMENTATION -- EXPERIMENTATION-DEMONSTRATION LABORATORY
INSTRUCTION SHEET

TITLE: MEASUREMENT OF LEVEL USING INFERENTIAL TYPE INSTRUMENTS

OBJECTIVES:

1. Determine the relation between pressure and depth as measured with the Diaphragm-Box System and with the Bubbler System.

GENERAL INSTRUCTIONS:

1. Measure and record the temperature of the liquid in the tank so that readings can be referred to standard conditions.

EQUIPMENT, TOOLS AND MATERIALS:

1. Diaphragm-box system
2. Bubbler system
3. Low pressure air supply
4. Water supply
5. Controlled level tank
6. Supply of liquids of different specific gravities

PRECAUTIONS:

1. Check all pipe joints for leaks.
2. Check provision for protecting air pressure recorder against excess pressure.
3. Check sight-feed bubbler for proper liquid level.

PROCEDURAL STEPS:

1. Using the diaphragm box, plot pressure as a function of the depth of the box. Repeat the experiment, using different liquids such as methanol or ethylene glycol, if available.
2. In a tank with controlled depth, use a bubbler system to measure liquid depth. Plot pressure vs. depth for liquids of different specific gravities. Consider any problems encountered in this determination.
3. Plot pressure vs. height of liquid for a series of liquids of different specific gravities. Determine feasibility of ascertaining level of liquid in this manner.
4. Using available force-balance pressure devices, compare their performance with the diaphragm box, or bubbler system.
5. Evaluate all devices in terms of their accuracy and ease of use.

REFERENCES:

1. Eckman, D. P. Industrial Instrumentation
   John Wiley & Sons, New York - 1950
2. Clarridge, Ralph E. and B. Chester Delahooke Fundamentals of Temperature and Pressure Instruments
   Delmar Publishers, Albany, New York - 1947

LESSON SHEET

Pressure Limit Controls

OBJECTIVES

The construction, operation and use of pressure limit controls.

INFORMATION

The National Board of Fire Underwriters require that all automatic oil fired steam boilers be protected from excessive pressures by an approved automatic pressure limiting device. This limiting control should be connected into the hot line on the supply side of all other burner circuits.

Most pressure limiting controls are actuated by a copper bellows which expands as the pressure increases. The motion of the expanding bellows is transmitted by means of a link bar to a pair of contacts or a mercury switch. When the pressure reaches the high point at which the control is set,the contacts or mercury switch snap opens,breaking the supply circuit to the burner. When the pressure drops, reverse action takes place. The contracting bellows cause the contacts to snap shut,closing the burner supply circuit.

The Mercoid DA-31 pressure controls are actuated by a bourdon tube instead of a bellows. A bourdon tube is a curved piece of metallic tubing scaled at one end. The tube is rigidly supported in the instrument case at the open end, the scaled end being free to move. As the pressure increases in the tube, it tends to straighten out. This motion is transmitted to the mercury switch by means of a link bar. As the pressure decreases within the tube, it tends to resume its original curved shape.

Pressure controls should always be mounted on a pig tail syphon to provide an air seal between the control and the boiler. This is to prevent the entrance of live steam into the bellows or tube of the control.

As the pig tail syphon tends to straighten out when under pressure, it will tilt the control slightly. To prevent this tilting from interfering with the action of the control, the loop of the syphon should be at a right angle to the face of the control.

REFERENCES

NBFU Pamphlet No. 31 Rule 20 b & c.
Mercoid, M-H and Perfex catalogs and manuals.

PROCEDURE

1. Read the above information and reference over carefully.

2. Obtain a bellows and a bourdon tube type of pressure control from the stock room.

3. Note how the cut-in and cut-out points are adjusted on a Mercoid Control.

4. Note how the cut-in and cut-out points are adjusted on a Penn, M-H or Perfex control.

Answer the following questions:

1. What is meant by the differential of a pressure limiting control?

2. How is pressure cut-out point found on a Penn, M-H or Perfex control?

3. What is the purpose of the pig tail syphon? How should it be mounted?

INFORMATION SHEET TS 8

TOPIC System Thermometers

AIM Understanding the Speed of Response of System Thermometers

The speed of response of any system thermometer is dependent on one or more of the following factors:

1. Type of thermometer
2. Mass of filling medium
3. Mass of bulb
4. Material of bulb
5. Length of capillary
6. Existence and mass of socket
7. Agitation or stratification of process material
8. Specific heat of process material
9. Conduction characteristics of thermometer bulb mounting
10. Condition of the surface of the bulb or socket

The speed of response of a thermometer is a heat transfer problem. The filling medium of the bulb must absorb BTU's from the process in order for the thermometer system to respond. The total rate of absorption is dependent on the factors listed above. Taking them one at a time, here are a few things to remember:

1. Type of thermometer. Inherently, the gas-filled thermometer is the fastest. Certain design factors work against this; depending on manufacturer, generally the vapor-pressure and liquid-filled systems give the fastest response.

2. Mass of filling medium. Theoretically the gas-filled thermometer having the lowest mass of filling medium should be the fastest, but internal transfer of heat through the gas slows down the response. Our choice here is either vapor-pressure or a liquid-filled system using a sensitivity filler in the bulb to cut down on the mass of filling medium.

3. Mass of bulb. The bulb must heat up before the temperature change is felt by the filling medium. The greater the bulb mass, the slower the response.

4. Material of bulb. Good conductors of heat, like copper, make for a fast response. Poor conductors like steel are slower.

5. Length of capillary. From a practical viewpoint, the longer the capillary, the slower will be the response.

6. Existence and mass of socket. Sockets are just another heat barrier. Sockets definitely slow up response. To help matters response-wise, always, when possible, fill the interspace between the socket and the bulb with oil or mercury.

7. Agitation. Bulbs always respond fastest in agitated materials, respond slowest in stratified materials.

8. Specific heat of process material. The more heat a material contains, the more rapidly it can give up heat to the thermometer bulb. Bulbs in material of high specific heat respond faster than those in materials of low specific heat.

9. Conduction characteristics of thermometer bulb mounting. If the bulb mountings are heavy and good conductors of heat, they may conduct heat away from the bulb so fast that not only is response slowed but the bulb may never reach the correct temperature.

10. Condition of surface of bulb or socket. Dirty, pitted, rough, corroded bulb or socket surfaces slow down response time. Keep all surfaces clean and bright.

QUESTIONS

1. For fast response would you use a copper or stainless steel bulb? Why?

2. Check thermometer manufacturers' catalogs and find out exactly how a "Sensitivity Filler" bulb is made.

3. All else being equal, would you expect a bulb to respond faster in water or in oil? Why?

4. Define:
   (a) specific heat
   (b) agitation
   (c) heat conduction

INSTRUMENTATION

COURSE OUTLINE

I. MEASURING PRINCIPLES
- A. Pressure Gages
- B. Liquid and gas flow measurements
- C. Liquid level measurements
- D. Temperature Measurements
- E. Humidity measurements
- F. Specific gravity measurements
- G. Viscosity measurements

II. MEASURING PRINCIPLES (ELECTRICAL)
- A. Electrical pressure transducers
- B. Electrical flow devices
- C. Electrical level transducers
- D. Electrical temperature transducers
- E. Potentiometric devices
- F. Indicating, recording, registering equipment
- G. Analytical instruments
- H. Radiation transducers
- I. Humidity measuring devices

III. TELEMETRY AND CONTROL PRINCIPLES
- A. Process characteristics, static
- B. Process characteristics, kinetic
- C. Component and system response
- D. Energy characteristics of the process
- E. The block diagram
- F. Feedback control systems, open, closed loop
- G. Pneumatic and hydraulic controllers, final operators

IV. INSTRUMENTATION ELECTRONICS
- A. Auxiliary electrical devices
- B. Data recording and storage
- C. Control of temperature, energy, speed, motion
- F. Electrical logic systems
- G. Electrical position finding systems
- H. Numerical control of machines

V. CONTROL SYSTEMS ANALYSIS

A. Control of DC energy to resistive load
B. Transistor amplifiers
C. Silicon controlled rectifiers
D. Magnetic amplifers, saturable core reactors
E. Electrical generators, amplidynes, servomotors
F. Thyratron control
G. Ignitron control
H. Relays, magnetic, other logic and control devices
I. Solid state devices, transistors diodes
J. Frequency responses of components
K. Feedback control
L. Controllers and their response

VI. COMPUTER PRINCIPLES AND SYSTEMS

A. Development of computing systems
B. Fundamentals of analog computers
C. Applications of analog computers
D. Principles of digital computers, elements
E. Peripheral equipment (on-off line)
F. Theory of programming computers
G. Applications in process and numerical control

VII. STANDARDIZATION AND CALIBRATION

A. Calibration of laboratory standards
B. Calibrations of plant standards
C. Overhaul, calibration, adjustment of pneumatic instruments
D. Overhaul, calibration, adjustment of electrical instruments

VIII. INSTRUMENT SHOP PRACTICES

A. Safety rules and precautions
B. Organization and function of instrument shop
C. Classification of commercial instruments
D. Records and documentation required
E. Test and alignment fixtures
F. Performance testing